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Abstract

OXIDE FUEL FABRICATION AND PERFORMANCE

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In the past five years, there has been a systematic approach in the United States to design formulation, fabrication development, and performance testing of uranium oxide type fuels primarily for water and steam reactors. A basic effort has been carried out in determining physical, mechanical, and corrosion properties under irradiation and coolant environment conditions of the individual components of the fuel. Simultaneously, extensive in-reactor testing at various thermal and life conditions has provided significant operating and engineering test data on many fuel types. These data allow reliable quantitative evaluation of oxide fuels aimed at economic central station power applications. In all studies undertaken, fuel performance information has been preceded by the development of fabrication techniques suited to specific geometries. In general, fabrication techniques were aimed toward to improvement of thermal output, increase of life span of a given core, minimization of parasitic neutron absorption, and reduction of fabrication costs.

Fabrication processes include ceramic grade pelleted fuel (93-97% theoretical density) and high density compactible powder, either vibratorily compacted (83-89% T. D.) or followed by cold working (to 92% T. D.) or hot working (to 94% T. D.). The claddings used for water and/or steam applications include zirconium alloys, austenitic stainless steels, and, more recently, nickel alloys.

Statistically significant numbers of fuel elements have been irradiated to peak burnups ranging up to 35×10^{20} fissions/cc and at maximum heat flux values up to 700 000 Btu/hr.-sq. ft. The studies included water and steam environments with operation in the 550-650F temperature range, and also superheated steam environment with operation in the 1200-1300F clad temperature range.

Zircaloy - 2 clad oxide fuel has shown generally favorable performance at the conditions listed. The encouraging early results with Incoloy as a superheat fuel clad has initiated interest in it also for lower temperature steam environments.

Austenitic 18 Cr - 8 Ni stainless steel clad fuel, operating under stressed conditions, exhibited some failures in in-reactor tests after about 1.6 to 3.7 x 10^{20} fissions/cc peak burnup. The metal attack has been of an intergranular nature with the material either in the unsensitized state (water coolant) or sensitized condition (superheated steam). Cracking has occurred in the regions of highest thermal output, indicating a stress and environmental dependency.

Two other important fuel performance trends have been evidenced: a) Intentional and service defects in the clad exposing the UO_2 to the coolant indicate a much lower release of radioactivity into the coolant environment than had originally been expected. Once the faulty fuel is removed, there appears to be negligible residual activity carried in the coolant. b) Some 0.5"OD Zr-2 clad uranium oxide rod fuel has been operated at a heat flux of about 1 400 000 Btu/hr-ft^2 for about 3 x 10^{20} fissions/cc maximum burnup. With about 70% of the UO_2 molten at the areas of maximum thermal output, there is no evidence of clad deterioration as long as adequate heat transfer exists in the coolant.